Generality of relationships between leaf pigment contents and spectral vegetation indices

Lea Hallik[1, 2, 6], Taras Kazantsev[2,3], Andres Kuusk[1], Jeroni Galmés[4], Magdalena Tomás[4], Ülo Niinemets[2, 5]

[1]Tartu Observatory, Observatooriumi 1, Tõravere, 61602 Tartumaa, Estonia

[2]Institute of Agricultural and Environmental Sciences, Estonian University of Life Sciences, Kreutzwaldi 1, Tartu 51014, Estonia

[3]Scientific Centre for Aerospace Research of the Earth, Institute of Geological Science, NASU, Gonchara str. 55-b, 01601, Kyiv, Ukraine

[4]Research Group on Plant Biology under Mediterranean Conditions, Departament de Biologia, Universitat de les Illes Balears, Carretera de Valldemossa Km 7.5, 07122 Palma de Mallorca, Illes Balears, Spain

[5]Estonian Academy of Sciences, Kohtu 6, 10130 Tallinn, Estonia

[6]Corresponding author e-mail: lea.hallik@to.ee

Springer Journal – Regional Environmental Change

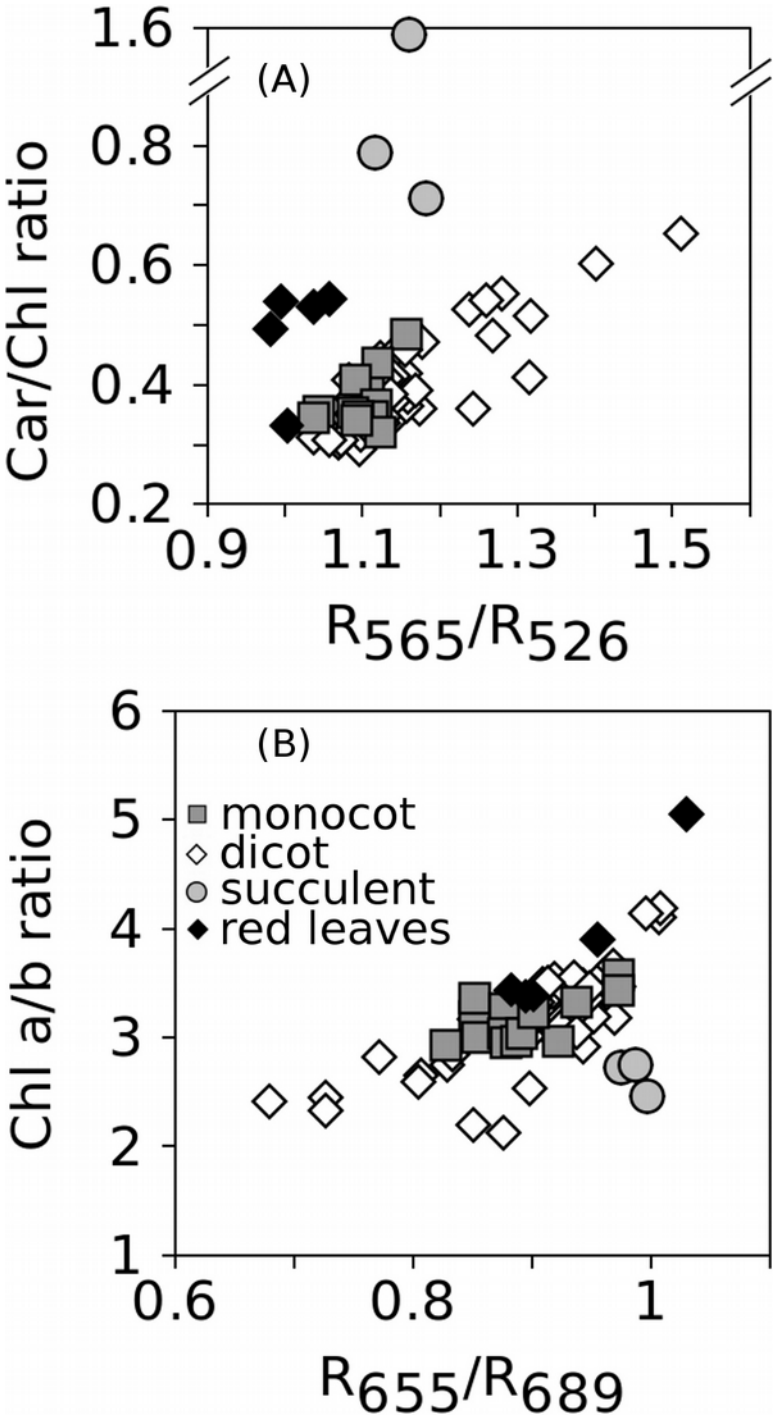
Appendix 3. Summary of the best wavelengths for predicting leaf pigments content: chlorophyll a (Chla), chlorophyll b (Chlb), total chlorophylls (Chla+b), total carotenoids (Car), chlorophyll a to b ratio (Chla/b) and carotenoids to chlorophyll ratio (Car/Chl). Six types of vegetation indices (VI) were calculated across whole visible spectral region and near-infrared plateau (400 nm – 900 nm): Simple Difference (SD), Simple Ratio (SR), Normalized Difference (NSD), Derivative Difference (DD), Derivative Ratio (DR) and Normalized Derivative Difference (NDD).

Target	Type of VI	max correlation			Pigment specific* max correlation		
		λ_1, nm	λ_2, nm	r2	λ_1, nm	λ_2, nm	r2
Chla	**SD= $R_{\lambda 1}$-$R_{\lambda 2}$**	735	745	0.837	735	745	0.837
	SR= $R_{\lambda 1}$/$R_{\lambda 2}$	736	751	0.841	736	751	0.841
	NSD=($R_{\lambda 1}$-$R_{\lambda 2}$)/ ($R_{\lambda 1}$+ $R_{\lambda 2}$)	737	750	0.837	737	750	0.837
	DD= $D_{\lambda 1}$-$D_{\lambda 2}$	748	762	0.871	748	762	0.871
	DR= $D_{\lambda 1}$/$D_{\lambda 2}$	730	719	0.833	730	719	0.833
	NDD=($D_{\lambda 1}$-$D_{\lambda 2}$)/ ($D_{\lambda 1}$+ $D_{\lambda 2}$)	525	748	0.860	525	748	0.860
Chlb	**SD**	738	748	0.788	642	686	0.443
	SR	737	750	0.791	690	611	0.573
	NSD	738	748	0.788	615	690	0.546
	DD	748	762	0.829	609	837	0.512
	DR	739	719	0.792	673	618	0.399
	NDD	525	749	0.804	679	690	0.431
Chla+b	**SD**	735	745	0.828	607	620	0.659
	SR	736	750	0.832	762	579	0.715
	NSD	737	750	0.828	417	589	0.677
	DD	748	762	0.866	429	743	0.609
	DR	730	719	0.827	711	535	0.537
	NDD	525	748	0.850	543	764	0.567
Car	**SD**	741	751	0.700	525	647	0.491
	SR	741	752	0.700	518	669	0.410
	NSD	742	752	0.697	519	664	0.367
	DD	748	762	0.744	516	547	0.580
	DR	743	728	0.718	561	744	0.654
	NDD	516	747	0.760	561	726	0.586
Chla/b	**SD**	658	688	0.384	495	683	0.299
	SR	655	689	0.391	655	689	0.391
	NSD	655	689	0.391	655	689	0.391
	DD	613	638	0.319	613	638	0.319
	DR	467	753	0.336	467	754	0.333
	NDD	466	743	0.340	466	743	0.340
Car/Chl **	**SD**	535	553	0.584	535	553	0.584
	SR	565	526	0.657	565	526	0.657
	NSD	526	565	0.657	526	565	0.657
	DD	539	800	0.552	540	800	0.533
	DR	536	566	0.513	536	566	0.513
	NDD	510	645	0.478	510	645	0.478

* Pigment specific max correlation: Only these vegetation indices which do not have stronger correlation with any other pigments tested.

** Succulent species (*Aeonium percarneum*) was removed from analysis

Appendix 4. (A) Simple ratio of reflectance in green spectral region at 565 nm and 526 nm predicting leaf carotenoids to chlorophyll ratio (Car/Chl). (B) Reflectance in red spectral region at 655 nm and 689 nm predicting chlorophyll a to b ratio (Chl a/b).



Appendix 5. Examples of leaf reflectance spectra. Light green – typical green leaf (*Lantana camara*); dark green – leaf with higher chlorophyll content than average (Ilex aquifolium); red – visually red leaves with high anthocyanins content (*Lantana camara*); pink – visually red leaves of *Protea sp*. (x-axis wavelengths [nm] and y-axis reflectance)